PLANT BIODIVERSITY AND MALNUTRITION: SIMPLE SOLUTIONS TO COMPLEX PROBLEMS

Theoretical Basis for the Development and Implementation of a Global Strategy Linking Plant Genetic Resource Conservation and Human Nutrition

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ABSTRACT

Given the difficulty of precisely identifying optimal diets, diversity provides an intrinsic buffer against uncertainties posed by lack of knowledge and by environmental change. Plant biodiversity offers useful perspectives on a number of issues of contemporary scientific and public health importance including, micronutrient deficiency and bioavailability, nutrition and disease, the nutrition transition, and medicinal and functional activities of plants. Globally, simplification of the diets of large numbers of people to a limited number of high-energy foods as a result of urbanization and socioeconomic changes presents unprecedented obstacles to human health associated with emerging diseases such as diabetes, hypertension and cancer. Greater use of plant biodiversity based on scientific evaluation of plant properties, cultural support programs, dietary education, innovative processing and marketing provides a possible avenue for mediating the impacts of change. The diverse nutrition and health functions that plants serve in traditional culture, and indigenous knowledge of plant diversity, offer potentially valuable solutions that enable biodiversity to address the problems facing contemporary society. This paper summarizes empirical evidence supporting the hypothesis that dietary diversity is essential for health and that biodiversity can be equated with dietary diversity. Further population studies on the relationship of dietary diversity including in plant varieties and health as well as research into mechanism through which diversity affects individual health are needed to test the validity of this hypothesis. Nutritional blindness is presented as a case where attention on one nutrient, vitamin A, overshadows important diseases such as cataracts and the potential importance of plant resources in mediating their effects.

Key words: dietary diversity, functional food, biodiversity, indigenous knowledge

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BIODIVERSITE DES PLANTES ET MALNUTRITION: DES SOLUTIONS SIMPLES A DES PROBLEMES COMPLEXES

Base théorique pour le développement et la mise en oeuvre d'une stratégie globale combinant la conservation des ressources génétiques des plantes et la nutrition humaine

RESUME

FRENCH

Au vu de la difficulté d'une identification précise d'un régime alimentaire idéal, la diversité offre une protection intrinsèque contre les incertitudes liées au manque de connaissances et aux changements de l'environnement. La biodiversité des plantes offre des perspectives utiles relatives à plusieurs questions ayant une importance scientifique et de santé publique d'actualité, y compris les carences en micronutriments et la biodisponibilité, la nutrition et la maladie, la transition alimentaire, et les activités médicinales et fonctionnelles des plantes. Au niveau mondial, la simplification de l'alimentation d'un grand nombre de personnes à une sélection limitée d'aliments à forte teneur énergétique suite à l'urbanisation et aux changements socio-économiques entraîne des conséquences sans précédent pour la santé humaine relatives aux maladies émergentes telles que le diabète, l'hypertension et le cancer. Une meilleure utilisation de la biodiversité végétale basée sur une évaluation scientifique des propriétés des plantes, des programmes de soutien culturel, une éducation alimentaire, des méthodes de production et de marketing novatrices offrent une avenue potentielle pour réduire l'impact du changement. Les fonctions nutritives et sanitaires diverses qu'ont les plantes dans la culture traditionnelle, et la connaissance indigène de la diversité des plantes, offrent des solutions potentiellement précieuses qui permettent à la biodiversité de faire face aux problèmes confrontant la société contemporaine.Le présent article résume les bases factuelles empiriques qui soutiennent

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l'hypothèse que la diversité alimentaire est essentielle à la santé et que la biodiversité est assimilée à la diversité alimentaire. Des études ultérieures sur la population sont nécessaires pour tester la validité de cette hypothèse concernant la relation entre la diversité alimentaire (y compris dans les variétés de plantes) et la santé, ainsi que des recherches sur le mécanisme permettant à la diversité d'affecter la santé individuelle.

La cécité nutritionnelle est présentée comme étant un cas où l'attention portée à un nutriment, la vitamine A, occulte des maladies importantes telles les cataractes et l'importance potentielle des plantes disponibles pour mitiger leurs effets.

Mots clés: diversité alimentaire, aliments fonctionnels, biodiversité, connaissance indigène

INTRODUCTION

Simple solutions are the best ones, or so we are led to believe. That single characteristics of food or a few species and genotypes are typically the focus of international initiatives in nutrition, food security and agriculture might therefore seem appropriate. While understandable in relation to the severity of problems of micronutrient deficiency and food insecurity, for large population segments in Africa and other developing areas, targeted approaches, however, inherently overlook the complex nature of human-environmental relationships or the multi-factorial nature of human diseases and health.

Given the complexity of human physiology and of food composition, and therefore the difficulty of precisely identifying optimal diets, diversity provides an intrinsic buffer against uncertainties posed by lack of knowledge and by change. In this light the solution to many of the world's diet-based problems is inherently complex, while simultaneously fundamentally simple.

Plant foods represent the largest segment of dietary diversity. Within this context the International Plant Genetic Resources Institute (IPGRI) is currently developing a global strategy to incorporate greater consideration of nutrition into its programs on conservation and use of plant genetic resources (PGR) [1]. This paper presents the theoretical background for IPGRI's leadership in promoting and coordinating this initiative and its implementation.

NUTRITIONISTS AS BROKERS OF DIVERSITY

Nutritionists understand well the importance of diversity in diet. Certainly graduates of nutrition programs in northern hemisphere countries appreciate the complexity of and limitations on scientific understanding of dietary-health relationships in industrial populations, but tend to put this perspective aside in Africa. In fact, as evidenced by the content of contemporary international journals, what sustains the discipline is investigation into the intricacies of the dietary basis of disease, and increasingly the functional diversity of food beyond that defined by essential nutrients.

The relatively fewer studies on actual nutrients tend to come mostly from work carried out in impoverished communities in developing countries. Here nutrition is characterized by identifying problems and solutions that target single nutrients or disease concepts such as anemia or vitamin A deficiency - usually disconnected from broader ecological or medical factors.

African nutritionists might equally be accused of simplifying the developing country context, whether in acquiescence to expertise and funded interventions from abroad, as a result of their training in Northern universities, or in rational response to the acute reality of undernutrition in the communities with which they work.

However, my personal observation is that African nutritionists understand complex relationships better than anyone. In contrast to the sometimes theoretical perspectives of their colleagues brought up in industrial societies, African nutritionists typically have deep and personal connections with local communities and subsistence systems. Not only do they know the diversity of crops, animals and cuisine that characterize intact systems, but they better appreciate the holistic understandings inherent in traditional cultural systems of health and diet.

Guided by the need for pragmatic approaches to the complex social and biological determinants of malnutrition, African scientists usually recognize especially well the multiple levels from which solutions must proceed. In fact, African nutrition science can and should be making a larger contribution to global thinking and awareness of the essential connections among socio-cultural considerations, biodiversity and health such as has been promoted by discussions on Food-Based Dietary Guidelines (FBDG) [2].

In the global arena, converging evidence supports the importance of diversity, the consequences of simplification of human ecosystems, and the need for multi-dimensional solutions to the problems that result. Primarily this evidence comes from clinical and

experimental sciences, epidemiology and traditional wisdom. In addition to briefly summarizing the nature of this evidence, this paper offers a case study in relation to one of the major nutrition problems - dietary blindness and vision loss.

The underlying hypothesis that dietary diversity is essential for health and that biodiversity equates with dietary diversity can define theoretical tests of its validity and applied action emerging from the insights it offers.

DIETARY DIVERSITY AND HEALTH

A handful of epidemiological studies from the USA and Europe [3,4] along with a few case studies from Africa [5-7] and Asia [8] uphold the conventional wisdom concerning the benefits of a varied diet, particularly in fruits and vegetables. Nutritional quality of the diet does improve with consumption of greater food diversity [5,9], as do measures of child nutritional status and growth [5,10]. Functional properties of dietary components likely play an important role [11,12].

Nutritional Value of Crop Varieties and Species Diversity in Traditional Diets

Although data on the composition of wild and cultivated biodiversity in most developing regions is grossly incomplete, such resources unquestionably make essential contributions to dietary adequacy [13-17]. These continue to be ignored in dietary surveys, in Food and Agriculture Organization (FAO) Food Balance Sheets and in national and international policy and decision-making [18]. Meanwhile laboratory research steadily identifies indigenous species with exceptional nutritional properties [19]. Studies on home gardens have made the links between diversity and nutritional status [20-22]. In exceptional cases assessment of the contribution of gathered species for specific nutrients has been clearly demonstrated [8,23,24].

Documentation of the contribution of crop varieties to nutrition and health has received even less attention. Farmer-based research demonstrates the wealth of traditional knowledge and beliefs on the health, sensory and culinary properties of local varieties [25]. For major crops such as rice [25], maize [26], potatoes [27] and sweet potatoes [28] screening of accessions, while incomplete, clearly documents wide variation in nutritional and functional properties that undoubtedly has implications for nutritional status of populations and individual consumers (in addition to its usefulness to plant breeders). The potential genetic variation within neglected and under-utilized species [29,30] has been even less documented.

Functional diversity in an African context

Traditional African concepts of diet often include associations with health that, generally speaking, refer not to nutrients but rather to specific functional properties. Some traditional concepts such as tonics or strengtheners may be understandable in nutritional terms. Other food attributes relate to physiological and pharmacological properties and can be supported by scientific investigations in these areas [31].

Potential health-related functions of indigenous dietary plants include antibiosis, immunostimulation, nervous system action, detoxification, anti-inflammatory, anti-gout, antioxidant, glycemic and hypolipidemic properties. For example, the Luo of western Kenya and Tanzania attribute action against disturbances of the gastrointestinal tract to the leafy vegetables that are an important component of their traditional diet. Among these *Solanum nigrum*, in particular, has strong activity against the protozoan parasite *Giardia lamblia* [32]. Additionally we have investigated the functional activity of dietary additives and masticants of the Maasai [33].

As such, functional activities on human health can be attributed to non-nutrients such as phytochemicals and fiber, as well as quality of energy sources, diversity of function and of chemical composition that add further dimensions to the diversity inherent in the food and medicinal plants used around the World [11,12,31].

Additional research to substantiate the relationship between dietary diversity and health in other contexts is warranted. A link between biodiversity and health outcomes would be strengthened by focusing such population studies at the level of food species and genotype and by exploring further the potential mechanisms through which diversity affects health of individuals.

GLOBAL CHANGE, DIET AND HEALTH

Globally, simplification of the diets of large numbers of people presents unprecedented obstacles to human health. Profound alterations in the relationships between humans and the ecosystems in which they live affect both disease and nutritional status [34].

Biological resources which are simultaneously affected by environment disturbances and the basis for human food systems play a central role both in terms of dietary change and to potential solutions. Degradation of diet coupled with environmental stresses challenges the health of human communities in unprecedented ways including through malnutrition, immunity and infection, environmental toxicants and oxidative stress [34].

Oxidative status plays an important role in many disease-states, including non-communicable diseases such as diabetes, cardiovascular disease, cancer and vision loss. Reduction in plant dietary diversity therefore has negative consequences as it leads to loss of antioxidant vitamins and non-nutrients that form a key component of the normal defense against oxidative stress [31].

Nutrition Transition

Diets in developing countries which are higher in energy, including vegetable oils and other fats heated under oxidizing conditions, and lower in diversity in fruits and vegetables than those consumed historically are associated with urbanization and socioeconomic changes. Consequently global rates of obesity and other non-communicable diseases can be expected to follow the epidemic trends already seen in Latin America and parts of Asia [35-37].

Data on dietary patterns for most populations are, in fact, inadequate to establish shifts in diversity of individual fruit and vegetable intake over time. However, national consumption trends in many cases are sufficiently profound to underscore emerging disease phenomena [37]. FAO Food Balance Sheets for several East African countries over the past 35 years show large reduction in per capita consumption of legumes that parallels an increase in the energy intake from edible oils; these changes are most marked in Kenya.

Senegal shows an even more dramatic increase in edible oil consumption with available calories from edible oil/ fat having increased since from 8% in 1963 to 20 % in 1998. While fats increase energy and facilitate vitamin A availability, the increase of total available calories from fat in the Senegalese diet from 18 to 29% suggests that a significant number of persons consume much more than recommended. At the same time there appears to be a drop by half (and by an even higher proportion in Kenya) in consumption of traditional cereals of millets and sorghum, foods that while demeaned for potential anti-nutrient, digestibility, and palatability deficiencies, offer potential antioxidant and hypoglycemic benefits relative to exotic cereals of wheat, rice and maize [38].

Little dietary research that has been conducted in African cities points to trends of decreased energy expenditure coupled with increased dependence on deep-fried foods derived from starchy sources such as cassava, wheat and potatoes and decreased intake of fresh fruits and vegetables [39]. For the poorest and most vulnerable segments of the population, these products often take the form of street foods of low nutrient density [40]. As a result, for large segments of the population in Africa conditions of energy over-consumption will likely co-exist with classic nutrient deficiencies and with infectious diseases [41].

With urbanization in sub-Saharan Africa projected to approach 50% of the population of the region in the next 15 years (**www.unchs.org/unchs/english/stats/table2.htm**), solutions to forestall the nutrition and health impacts of this trend are acutely needed. Greater use of plant biodiversity based on scientific evaluation of plant properties, cultural support programs, dietary education, innovative processing and marketing provide possible avenues for mediating the impacts of change.

NUTRITIONAL BLINDNESS: A CASE OF SINGLE-NUTRIENT PREOCCUPATION

Vitamin A deficiency is justifiably recognized as a micronutrient deficiency of global significance with a range of direct and synergistic effects on health. Xerophthalmia has major consequences on the well-being of children in impoverished communities. While solutions appropriately are sought on several fronts, the degree of preoccupation on this condition has potential impacts on awareness of and response to other health conditions.

Food-based strategies that increase intake of fat, preformed retinal from animal foods, and orange fruits and vegetables offer the greatest likelihood of alleviating this condition. In a practical sense, then, success most likely comes from increasing dietary diversity, which itself is highly dependent on alleviation of poverty [42].

Considering that for the populations most at risk the latter objective seems unrealistic in the contemporary context, alternative strategies are sought. However, conventional interventions including clinical and dietary supplementation and food fortification through processing or agricultural technology, while effective where warranted and adequately monitored, under normal circumstances often offer imperfect solutions for people in developing countries for economic, technical and cultural reasons [43].

Among the limitations of vitamin A strategies:

1. Single nutrient responses to identifiable deficiencies may occur at the expense of addressing multiple, usually more cryptic, deficiencies and fail to provide the balance necessary for long-term health.
2. Complex interactions between this nutrient and other food ingredients affect absorption and the relationship between nutrition and disease.
3. Current dietary approaches to vitamin A deficiency focus on a single health issue, xerophthalmia, at the expenses of other forms of blindness and vision impairment.

4. Approaches that limit dietary diversity, as represented in the extreme case by "biofortification", stand to skew the diet in ways that have a potential cascade of adverse effects.

More fundamentally, vitamin A deficiency is a symptom of profound dietary, socioeconomic and ecological determinants that must be addressed before this immediate problem can be authentically resolved.

Leafy Vegetables and Bioavailability of ß-carotene

Leafy vegetables (LV) represent one of the richest sources of biodiversity in African food systems and a potential rich source of ß-carotene [13]. However, the poor bioavailability of provitamin A in a number of studies has called into question the importance of these accessible, acceptable foods in the diets of local African communities [44]. Nonetheless many of the benefits of non-nutrients in LV may exceed those attributable to the ß-carotene or other nutrients.

For example, vegetable diets that make modest contributions to improving vitamin A status result in significant increases in serum levels of lutein, an antioxidant xanthophyll for which protective benefits in relation to ocular disease , as well as cardiovascular disease and cancer, are increasingly recognized as of importance to health [44, 45]. Such insights have potential significance in tropical countries where cataracts represent the major cause of blindness [46]. Ojofetimi [47] showed that Nigerian patients with cataracts had lower intake of fruits and vegetables than control subjects . Compilations of data on xanthophylls point to the richness of LV in these non-nutrient carotenoids; extension of these analyses to indigenous plant foods also is called for [48, 49].

In light of this important functional activity (and undoubtedly others), the single-minded attention on the limitations of LV and other plant foods as sources of provitamin A seems somewhat shortsighted [44].

Biofortification of Rice

While biofortification demonstrates the usefulness of plant genetic diversity on one hand, it also represents a curb on diversity. Likewise from a nutritional perspective, while biotechnologies have potential as useful tools in specific circumstances, as a widespread solution to vitamin A deficiency, biofortification seems simplistic and potentially harmful without thorough evaluation [50]. Certainly this technology has not been adequately assessed for efficacy or economic efficiency in real world contexts. While biotechnology offers long-term promise for addressing serious global problems, it is important that this dream does not blind us to the enduring problems of impoverished communities and the need to maintain funding for proven and present interventions.

Consider the case of the genetic modification of major staples for content of ß-carotene as exemplified by so-called "golden rice" [51]. Notwithstanding the fact that its nutritional efficacy or consumer acceptability cannot be addressed until the product is actually available, in rice-consuming countries in Asia where it could be beneficial, ecological, nutritional and sociocultural realities raise serious doubts [52].

Nepal, for example, has severe and well-documented vitamin A deficiencies [53]. While xerophthalmia and other conditions are an adverse outcome, the causal determinant in the Nepalese diet is over-preponderance of carbohydrates and cereals (mainly rice) and limited intake of fats and more diverse elements.

Adverse consequences of this diet include generally low content and bioavailability of vitamin A and antioxidants. Furthermore, white rice diets have potentially high glycemic indices and insulin-stimulating properties [54]. These may contribute to diabetes rates that are high for developing countries, myopia, and other diseases [55-57]. High levels of cataracts can be attributed in part to lack of antioxidants [58]. As causes of blindness and visual impairment, cataracts and myopia have been overshadowed by xerophthalmia [59].

Rice as the characterizing feature of this diet needs to be mediated in positive ways. However, promotion of rice for single attributes such as vitamin A will only exacerbate the adverse consequences of a high rice diet unless equal or greater attention is placed on increasing consumption of other foods. In this regard attention in this rice-based system needs to be directed to the sources of nutrients (including vitamin A and lipids) and functional components (such as non-provitamin A carotenoids and other antioxidants) that can compliment rice.

DIETARY ADAPTATION AND OPTIMIZATION

In contrast to such apparently simplistic and short-term approaches, rational use of dietary resources and application of knowledge concerning their value can define a sustainable course for optimal adaptation to the changes facing populations around the world [60].

Scientific insights into the relationships among environment, diet and health and the adverse consequence of current change offer essential tools for achieving novel solutions for problems arising from contemporary lifestyle changes [31]. Scientific evaluation of the properties of plant and animal foods is essential to this

objective. However, the lessons of the past represented by the wealth of indigenous knowledge of biological resources, ecosystems and traditional diets, as well as the diversity of resources themselves, are essential to the process of adaptation [37]. Documentation and study of the world's biocultural diversity should take high priority in this regard.

African food culture is an under-utilized vehicle in promoting positive dietary behaviour. Asian countries (as well as Mediterranean diets) again provide useful insights [2,37]. Countries that retain traditional diets with high consumption of plant foods are much less affected by cardiovascular disease, diabetes and other adverse consequences of the nutrition transition.

CONCLUSION

Plant diversity in human diet and medicine and the knowledge imbedded in cultural as an integral component of the complexity in human ecological systems offer a time-honoured buffer to destructive change. Plant resources coupled with the biocultural wisdom of traditional systems can make important contributions to address the serious problems of food insecurity and under-nutrition facing developing countries. Towards these ends plant genetic resources are both of profound utility and of inherent value [31].

Within the limited economic and technological options in a developing country context, the consequences of a shift to dietary simplicity are likely to be magnified as they limit peoples' capacity to adapt to changing circumstances. Initiatives that emphasize single nutrients and/or a limited number of foods may fail or produce adverse consequences in the long run as they limit the complexity and functional diversity of diets and possibly precipitate diseases-states that may be unpredictable. While simple solutions are indeed desirable, simplistic ones are not.

On the other hand holistic approaches to dietary diversity, resulting from the wide availability of diverse edible cereals and edible plants within a positive health culture and complimented by the application of scientific and technical knowledge, offer the potential to raise peoples' nutritional and health status in a sustainable way.

In the contemporary world where global change impacts traditional ecology in ways that threaten biodiversity and at the same time undermine human subsistence, health is a vital rationale for managing biodiversity and for conserving plant resources. The growing body of data supporting the premise that biodiversity can be equated with dietary diversity which in turn can be equated with health should then be the basis for further research and applied action.

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